

Land Use and Ecological Capital Assessment of China

Shi Peijun^{1,2}, Ye Tao^{1,2}, Pan Yaozhong², Li Jing², Li Xiaobing², Zhang Shuying²

1. Key Laboratory of Environmental Change & Natural Disaster, Ministry of Education of China;

2. College of Resources Science & Technology, Beijing Normal University, Beijing 100875, China

Abstract: Land use and Ecological Capital assessment is an extension of land use/ cover change research, and is one of the most important research objects of the Global Land Project (GLP). Based on the macroscopic measurement of Ecological Capital in China and combining ancient Chinese philosophy sayings about sustainable development, this paper put forward an index named “harmony” which is used to assess the harmonious state of Ecological Capital and Social Capital, and another index named “syncretizality” which is used to assess homeostasis of Ecological Capital and Social Capital. The “harmony” and “syncretizality” of each county in China is calculated. It is considered that, only when the relationship between human and nature is harmonious, the development is sustained. Among all kinds of adjustment measures, as the main way in which human modify the earth surface, land use is then the most effective and most important tool to harmonize the development of Ecological Capital and Social Capital. It would be very helpful for effective land resources utilization and sustainable development to implement “ecology oriented” land use planning, separating different land use into “productive land”, “living land” and “ecological land”, and to optimize land use pattern.

Keywords: land use; Ecological Capital assessment; “harmony” and “syncretizality”; “ecology oriented” land use planning

1. Introduction

There are two kinds of capital on the earth surface, which are Ecological Capital (Natural Capital) and Social Capital. Ecological Capital refers to material resources and ecosystem service offered by ecosystems, while Social Capital refers to social treasures from human laboring. These two capitals are contradictive, for the increase of Social Capital is at the cost of Ecological Capital. This conflict induced the argument of “ecological conservation” and “economical development” in the proposition of sustainable development. The aim of sustainable development is then to seek for a way to get a “win-win” mode of Ecological Capital and Social Capital. Nature determines the distribution pattern of Ecological Capital and Social Capital, while human want to get rid of this shackle and change the pattern when they are becoming more and more developed and skilled, which induced the fast changes in land use pattern and Ecological Capital pattern. In the past few years, the change and succession of land use and land cover on the earth surface has been paid highly attention to by IGBP and IHDP joint core project LUCC. From the driving forces of land use change to the mechanism of how land use drives land cover, and to the changes in ecosystem pattern and process induced by land cover change, a lot of researches has been done by scientists all over the world. The research on Ecological Capital origins from the paper named “The Value of the World’s Ecosystem Services and Natural Capital” published on “Nature” in 1997 (Costanza et al., 1997). With the progress in ecosystem service research, more and more attention has been paid to this seeming “new resource” which is becoming more and more exiguous. It is considered that it is the key issue to keep the health of the earth and develop sustainable to maintain and recover certain amount of Ecological Capital. As one of the parameters reflecting the land surface condition, change in land cover distinguishes the difference in quality, while change in

Ecological Capital indicates the difference in quantity. The Global Land Project (GLP) integrated recently has regarded the research on the impact of land system change on ecosystem service as one of its main objectives (IGBP, 2003). Thus, it is considered that Ecological Capital research is a progress in land use research (Figure 1). Land use and Ecological Capital assessment makes land use and ecological security research enters the period of quantitative research, which would be a milestone on the way to sustainable development.

2. Data Sources

Beijing Normal University has involved in land use and Ecological Capital assessment research since 2002. At first, a technical system of Ecological Capital measurement is put forward including remote sensing, filed investigation and statistical information (Shi Peijun et al., 2002). Then, the Ecological Capital in Inner Mongolia is measured using such a system (Zhang Shuying et al., 2004). After that, a macroscopic measurement of the whole China is done, including Ecological Capital in 1992, 1995 and 2000 (Pan Yaozhong et al., 2004), with a spatial resolution of 1000m*1000m. The remote sensing image of 1992 and 1995 is NOAA, while image of 2000 is SPOT_VGT. The details of the measurement and calculation are beyond discussion here, and can be found in relative references.

There are also data about Social Capital used in this paper, which are Gross Domestic Production (GDP) value of each county in both 1995 and 2000. These data come from statistical yearbooks of 1996 and 2001 of each province of China.

3. Patterns of Land Use and Ecological Capital of China

3.1 Land use pattern of China

Figure 2 is the map of land use of China. It can be seen that, in the east of china where the climate is relatively good, farm land lays where the land form is flat, while forest situated in mountainous or hilly regions. In western provinces, such as Inner Mongolia, Tibet, Gansu, Qinghai, Ningxia etc., limited by geographic position and climate, grassland is the main land use type, and desert and Gobi inlaid in it, which are familiar in arid and semi-arid regions.

3.2 Ecological capital pattern of China

From the Ecological Capital map of China in year 2000 (Figure 3), it can be seen that the high Ecological Capital region located in the forest areas in the east of China, including Changbai Mountain, Da Xing'an Mountains, Xia Xing'an Mountains, Qingling Mountains, HengduanShan Mountains, mountains in the southeast of Tibet plateau, hills in Zhejiang and Fujian Province, central Mountains in Taiwan, Hainan island, Tianshan Mountains, and Altai Mountains. 95% of the total Ecological Capital of this country is on the east of the line from Lhasa to Erlianhaote, with only 60% of the total area. On the west of the line, Ecological Capital per unit area is generally less than 200 RMB yuan/hm² except the North branch of Tianshan Mountains and Altai Mountains, while on the east, the highest value could reach 50000 RMB yuan/hm², which is 250 times more.

Comparing those two maps it can be found that, on larger scales, natural factors especially climate are most decisive, so it shows a regional differentiation between the west and the east in China. On the sub-scale, the pattern of Ecological Capital is almost the same with land use pattern: high Ecological Capital lies where the forests are; sub-high values matches the location of farmlands, including Northeast China Plain, North China

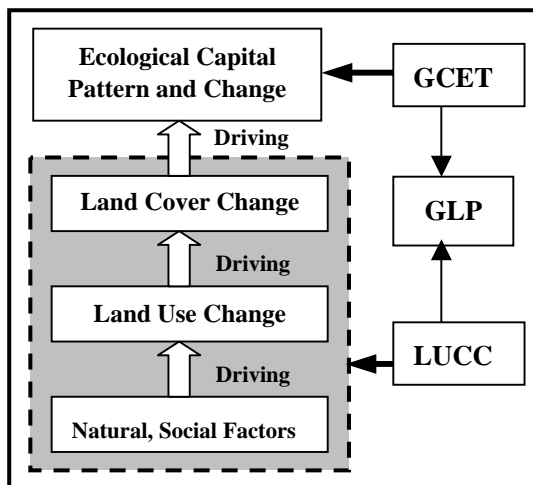
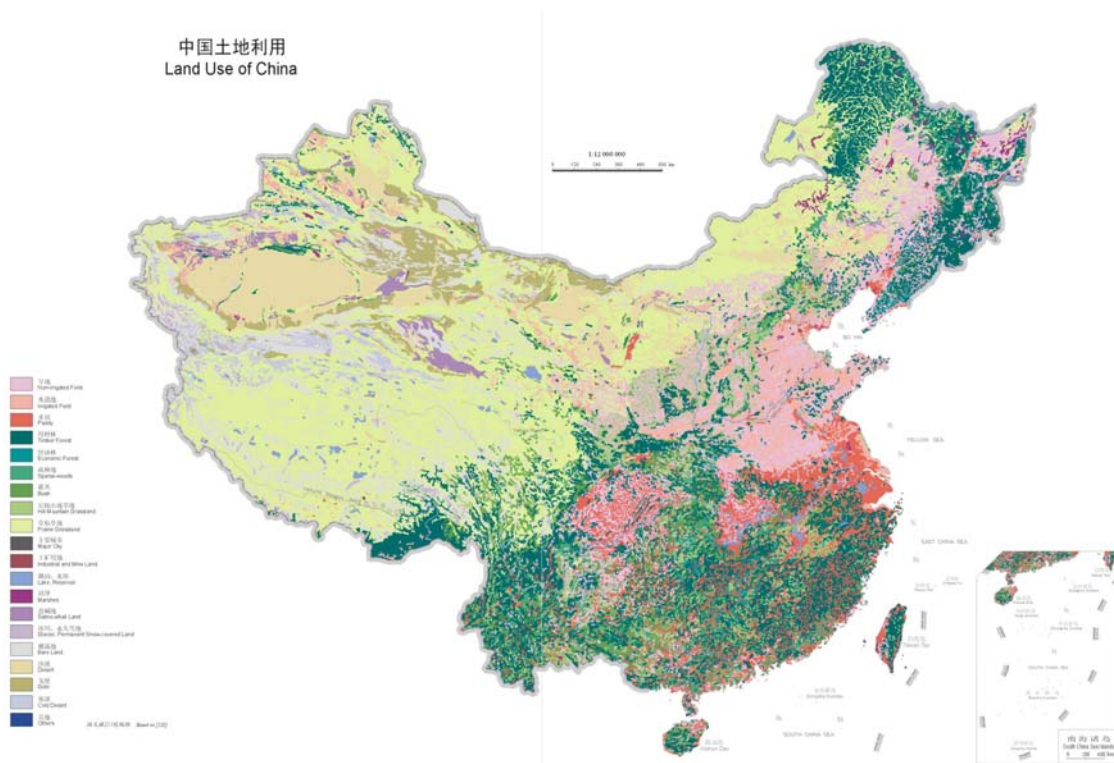


Figure 1 from LUCC research to land use and Ecological Capital research



Source: Shi Peijun et al., 2003

Figure 2 Land use map of China

Plain, Mid-lower Reaches of Yangtze River Plain, and Chengdu Plain; low values of Ecological Capital overlaps grassland regions largely, including vast Inner Mongolia Plateau, Tibet Plateau, and some areas in Xinjiang Province; while where the Ecological Capital “holes” are, there are always cities, industrial and mine land, deserts, and Gobi, etc. It is considered that the regional differentiation of Ecological Capital is the outcome of interaction between physical geographical factors and human activity. Among all kinds of human activities affecting earth surface, land use is the most direct one and most important one.

4. Harmony Assessment between Ecological Capital and Social Capital in China based on County Level

Ecological capital is the out come of natural ecosystem. The development of human society is based on the materials offered by ecosystem. Ancient human beings live where natural condition was very good. As a matter of fact, the development of society would inevitably induce losses in ecosystem, destroying matter basis of ecosystem service. Social and economic development is at the cost of both material resources and ecosystem service. It is reflected on the map (Figure 3) that, the Ecological Capital low value area or even Ecological Capital hole are always where the Social Capital is rich. Under the impact of out-of-order human activity, the Ecological Capital reduced sharply not only in the developed regions, but also in the vulnerable or bad natural condition areas. That is the very reason why the earth system becomes less healthy.

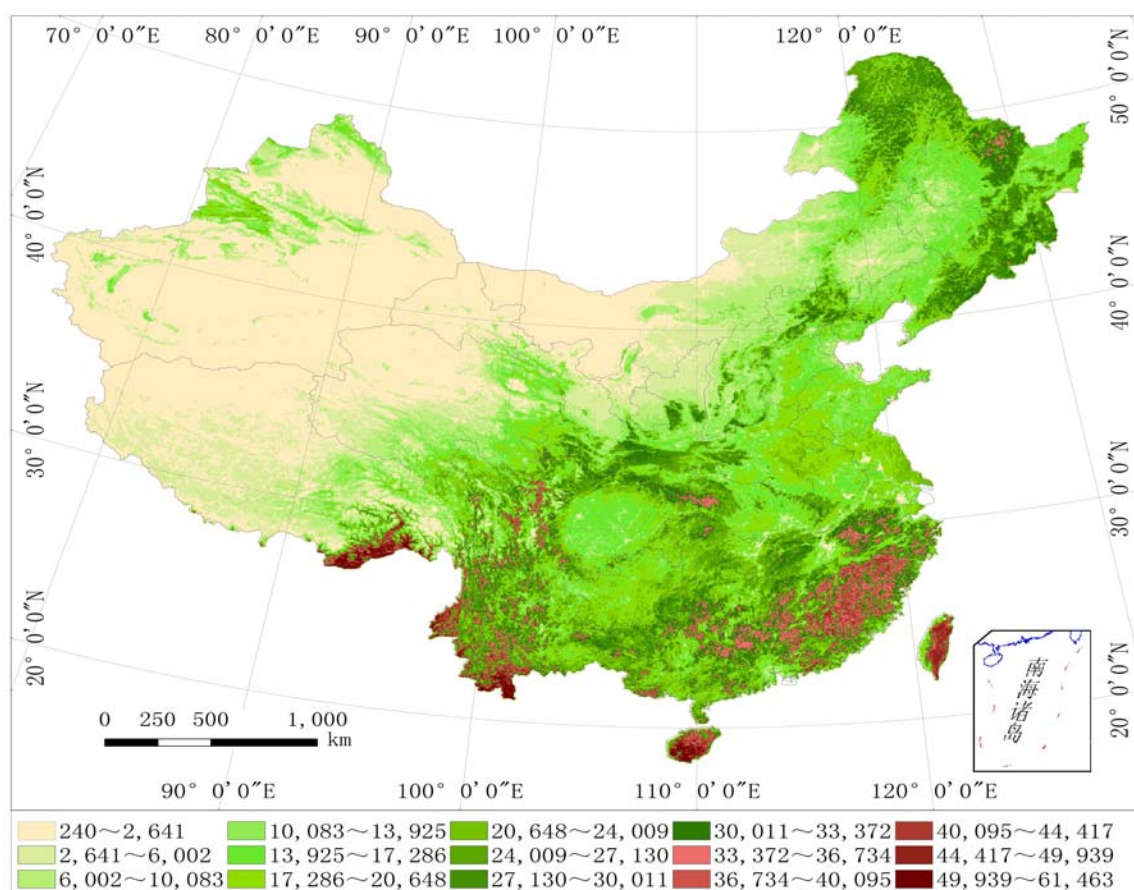
4.1 Harmonious state assessment of Ecological Capital and Social Capital

In ancient Chinese philosophy, there is a saying of “sky, land, human and harmony”. In this saying, sky refers to natural factors (planet earth) and natural driving forces (biogeochemical and biogeophysical processes), human refers to human dimension (social) and human driving forces (human activities, especially land use), and “land” refers to landscape pattern on the earth surface (land cover pattern, and Ecological Capital pattern et al.). Sky and the human are two driving forces of the earth system, while land is the medium of interaction between sky and human as well as the result of the interaction. “Harmony” is to reach a state that sky and human is harmonious on the earth surface, namely sustainable. From the point of view of Ecological Capital and Social Capital, it means that the development of Ecological Capital and Social Capital have to be balanced. In order to reflect the large difference between Ecological Capital and Social Capital, Shi Peijun et al. put forward an index system to measure the production of both ecosystem and society, namely “harmony” (P_s), using the ratio of Ecological Capital per unit area (ECP) and Grass Domestic Production per unit area (GDPP) (Shi Peijun et al., 2005):

$$P_s = \frac{ECP}{GDPP}$$

And the P_s value of each county in China is calculated, shown in Figure 4.

It can be seen from the figure that there is obvious east-west regional differentiation of P_s value of China. In the east, though the Ecological Capital is large, when compared to its Social Capital, it becomes exiguous. While in the west, though the value of Ecological Capital is low, when compared to its Social Capital, it is abundant. The ECP value of the west is more than GDPP value on average. Ecological Capital is very rich in Tibet, Xinjiang Province, Inner Mongolia Plateau, Daxing'an Mountains, and Xiaoxing'an Mountains, and especially in Tibet plateau, the ECP value is almost 100 times more than the GDPP value. In Daxing'an Mountains, Xiaoxing'ai Mountains and Hulunbeier Plateau, the ECP value is 50 times more than the GDPP value. In the east of China, ECP value is mostly the same with GDPP. High P_s value areas distributes mainly in mountainous and hilly regions.



Source: Pan Yaozhong et al., 2004

Figure 3 Ecological Capital of terrestrial ecosystem of China in year 2000 (RMB yuan/hm²)

The Ps value is less than 1 in relatively developed regions, e.g. main cities, metropolitans, and economic opening regions in the coast. Several metropolitans that authorized by most Chinese scholars can be identified in this map clearly, including Liaodong peninsula metropolitans, Beijing-Tianjin metropolitans, Shandong peninsula metropolitans, north China metropolitans, Yangtze River Delta metropolitans, mid-reach of Yangtze River metropolitans, SiChuan Basin metropolitans and Pearl River Delta metropolitans. In the east coast of China, from Liaoning Peninsula in the north to Pearl River Delta in the south, there is a low Ps value belt. The spatial distribution of Ps Value reveals the contradiction between the Social Capital and Ecological Capital, the cost of economic development of using material resources, and the irreversible land use change of urbanization, which induced destructive impact on Ecological Capital.

4.2 Homeostasis assessment of Ecological Capital and Social Capital

There is another saying in ancient Chinese philosophy about sustainable development, which is called “syncrization of nature and human”. The harmonious state of nature and human is not enough, as the speed of their development should also be balanced and coherent. Only when natural driving force and human driving force are dynamically balanced, the state can be harmonious. “Syncrization” can be regarded as the speed of Ecological Capital increase is the same with the speed of Social Capital increase. It means that, the development of Social Capital has to assort with the development of Ecological Capital, and the development of Ecological Capital should not be ignored when aspiring after Social Capital. In order to analyze the relative developing speed of these 2 capitals, Shi Peijun et al. put forward an index named syncrizationity (Rp) (Shi Peijun et al., 2005):

$$\frac{1}{Rp} = \Delta Ee = \frac{EC_{t2} - EC_{t1}}{EC_{t1}} \bigg/ \frac{GDP_{t2} - GDP_{t1}}{GDP_{t1}}$$

According to this equation, the relative developing speed of ECP and GDPP is calculated (Figure 5). This map reveals that, in the 5 years' time, the development of ecological capital and social capital of China are not balanced. In the west of China, the amplitude of ECP is only 1/4 of that of GDPP. Something is worse that as the most important ecological vulnerable region of China, large areas of Ecological Capital decreased, and the number of such counties takes 10 percent of total counties of China. In most parts of Tibet Plateau, mid and west of Inner Mongolia Plateau, Changbai Mountains in the northeast, the decrease of ECP is 2.5 times more than the increase of GDPP. The serious ecological destruction in Tibet Plateau induced flood disaster in Yangtze River and water resources shortage in Yellow River. The sharp decrease of Ecological Capital in Inner Mongolia resulted in dust storms in North China Plain. While the water-soil erosion in Northeast China is closely related to the ecological condition of Changbai Mountains. In the east of China, though it is better than that in the west, it is not optimistic. In most areas in the east, the amplitude of ECP is only half of that of GDPP, while the number of counties whose amplitude of ECP is equal to or more than that of GDPP are only 255, which takes only 10 percent of the total counties number. It is relative better ($0.5 \leq \Delta Ee < 1$) in the lower reach of Yellow River, the north of Anhui Province, Jiangsu Province, mid of Hubei province, east of Sichuan Province, Guangdong Province and Guangxi Province. It is worrying ($0 \leq \Delta Ee < 0.25$) in the upper reach of Yangtze River, Guizhou Province, north of Hunan Province, as well as main cities and metropolitans.

It is clear that ecological construction was ignored by some western provinces, which would do harm to ecological security of the whole country. The west developing strategy is implementing now, in which ecological construction should be paid enough attention to and “construct ecology industrially, and develop industry ecologically” (Shi Peijun et al., 2003) in order to maintain the vulnerable and critical ecological environment of

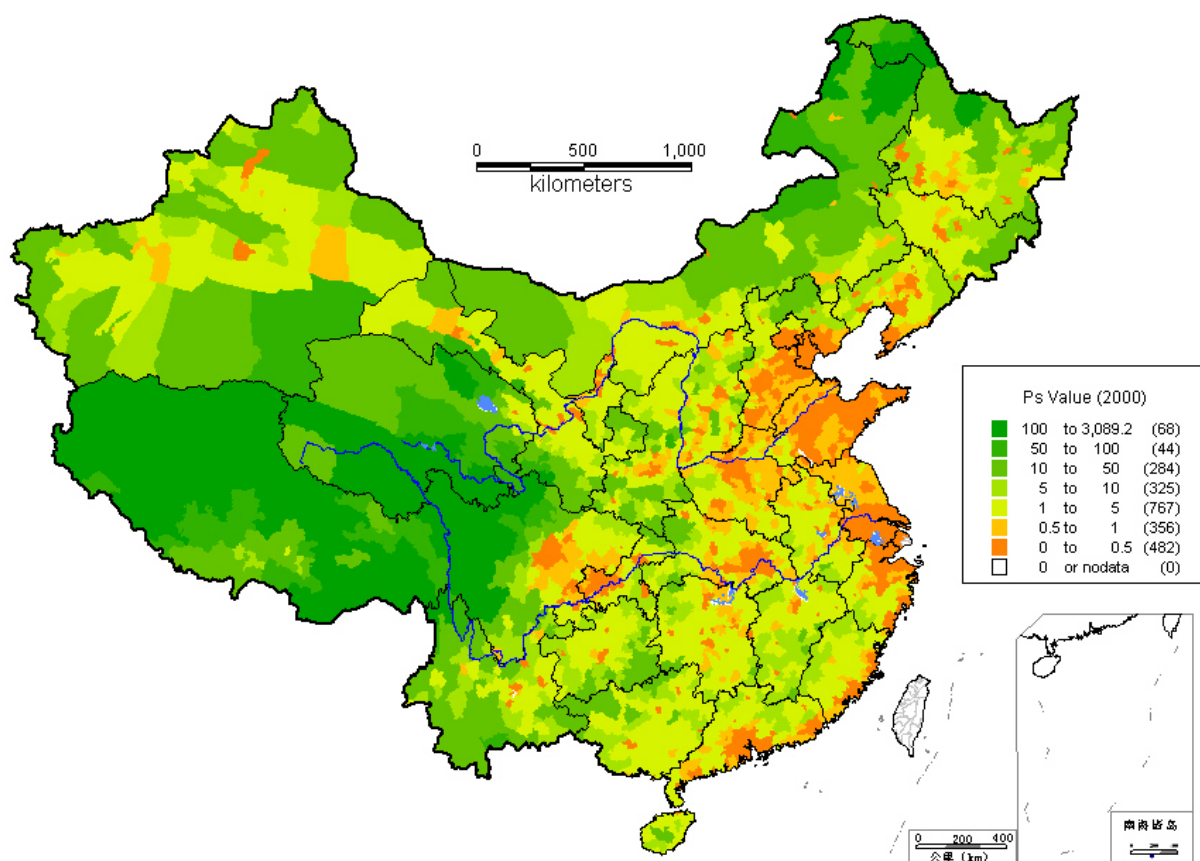


Figure 4 Ps value of China in year 2000

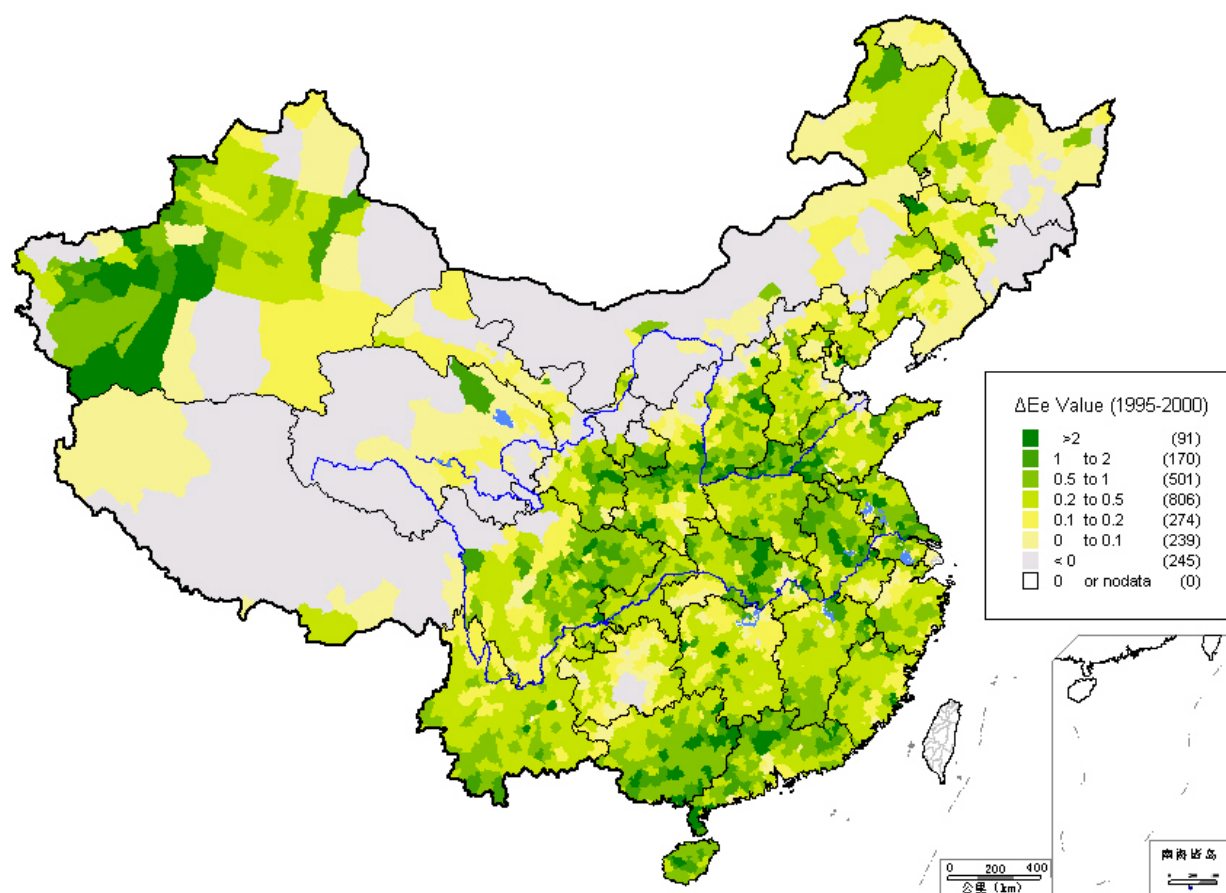


Figure 5 ΔE_e value of China (1995-2000)

the west. The eastern provinces should also be concerned about ecological construction, and try their best to balance the development of ecological capital and social capital. Otherwise, the ecological capital would not be able to support fast economic development, forming serious ecological burden, and even leading to ecological disasters.

5. Land Use Mode of Harmonizing Ecological Capital and Social Capital

The analysis above has pointed out that, Ecological Capital not only provides how much the ecosystem service is, but also the quantitative relationship between Ecological Capital and Social Capital. Then we could know the relationship between ecological conservation and economic development and which one should be paid more attention. With the progress in Ecological Capital research, the effect of Ecological Capital in sustainable development research would be more and more obvious, which makes it feasible to do quantitative assessment of sustainable development and adjustment in Social Capital and Ecological Capital. The adjustment of the relationship between these 2 kinds of capital has to start with human activities, among which land use is the most directive one as well as the most basic one.

Implementing “ecology oriented” land use planning, design ecosystem boldly and reasonably, to syncretise regional ecosystem and social system and reach the harmony state of nature and human. This is just the point of Pragmatic Ecological Science put forward by Margaret Palmer et al. last year (Margate Palmer et al., 2004). Different land use types shall be divided into 3 functional types, which are relevant “productive land”, “living land” and “ecological land”. “Productive land” mainly provide human with social production space, including industry land, farmland, and traffic land. “Living land” is where human live, including residence and public service land (enterprises, military establishments, ashes and so on). “Ecological land” provides man with ecosystem service, maintains ecological environment in critical and vulnerable regions, and ensures the health of both human and the earth system (natural conservation regions, forest, and wetlands).

On one hand, “ecology oriented” land use planning seeks for a reasonable structure of these three land use types. It can be realized through political and economic measures. In political measures, the Ecological Capital shall be brought into civil economy account, and different tax shall be imposed upon ecosystem service consumption according to different Ps values. In economic measures, Ecological Capital shall be brought into price system in order to adjust the supply and demand of material resources, and land market should be certified and the loss of Ecological Capital should be reckoned into land price when land use changes in order to conserve ecosystem service.

On the other hand, land use pattern adjustment is of much importance as well. Only the three land use types distributes reasonably, “ecology oriented” land use planning can work. The experiments in farming-pastoral zone in Inner Mongolia have proved that, “ecological construction in large areas while social production in small areas” is the most sustainable way for this region’s development (Shi Peijun et al., 2002). On the local scale, implement land use adjustment and landscape redesigning. On the regional scale, optimize land use pattern, make cities productive land and living land with high density and small area, make the circle around cities and critical and vulnerable regions ecological land, and make other areas the mosaic of productive land and ecological land. On the country’s scale, regionalize productive land, living land and ecological land, and balance the interest of each sub-region to ensure the ecological security and sustainable development of the whole country.

6. Conclusions

With the progress of global change research and the understanding of human-nature interaction, ecosystem service and Ecological Capital has been paid more and more attention. The GLP considers land as an entire system, and focus on its driving force, its consequence and integrated modeling. The close relationship between land system and Ecological Capital would be more and more concerned in the future. As the most important way that human affect the spatial pattern of Social Capital and Ecological Capital, land use would inevitably become the most basic way to harmonize the development Social Capital and Ecological Capital.

This paper does some basic research on land use and Ecological Capital assessment of China. Two index named “harmony” and “syncretizality” is put forward based on ancient Chinese philosophy, in order to reflect the harmonious state and homeostasis of Ecological Capital and Social Capital. The result of “harmony” assessment reveals that it shows east-west spatial differentiation between different regions in China and wide gap between Ecological Capital and Social Capital in a certain region. The result of homeostasis assessment shows that, in the east though the Ecological Capital increased, the speed of it was far lower than the Social Capital. In the west, the increase of Ecological Capital was too slow, and in certain regions the increase of Social Capital is at the cost of Ecological Capital. Ecological security of China is worrying.

“Harmony” and “syncretizality” would be very good director in harmonize Ecological Capital and Social Capital, then relationship between human and nature could be adjusted more definitely and purposefully. Besides the adjustment in the structure of ecological capital and social capital, pattern is also of much importance. Implementing “ecology oriented” land use planning, distribute “productive land”, “living land” and “ecological land” reasonably to maximum the profit of land resources utilization.

The further research on land use and Ecological Capital assessment shall focus on the affecting mechanism of land use change on Ecological Capital pattern, the optimized structure of Ecological Capital and Social Capital, deeper understanding of “ecology oriented” land use planning. Seeking for ways of optimization and adjustment in land use planning to harmonize Ecological Capital and Social Capital, the goal of sustainable development could be achieved then.

Acknowledgements

This paper is financially supported by National Natural Science Foundation of China Outstanding Youth Fund (No. 40425008).

References

- Costanza R, d'Arge R, Groot R, et al. (1997) The Value of the World' Ecosystem Services and Natural Capital, *Nature*, 387: 253-260.
- Emilio F. Moran (2003) News on The Land Project, *IGBP Newsletters*, 54(6).
- Shi Peijun, Pan Yaozhong, Chen Yunhao, et al. (2002) Technical System of Ecological Capital Integrated Measurement Using Multi-scale Remotely Sensed Data, *Advance in Earth Science*, 17(2): 169-173.
- Pan Yaozhong, Shi Peijun, Zhu Wenquan, et al. (2005) Quantitative Measurement of Terrestrial Ecological Capital of China, *Science in China (Series D)*, 34(4): 374~384.
- Zhang Shuying, Chen Yunhao, Li Xiaobin, et al. (2004) Measurement of Ecological Capital and Ecological Construction in Inner Mongolia, *Resources Science*, 26(3): 22-28.
- Shi Peijun. (2003) *Atlas of Natural Disaster System of China*. Beijing, Science Press.
- Shi Peijun, Zhang Shuying, Pan Yaozhong, et al. (2005) Ecosystem Capital and Regional Sustainable

- Development, *Journal of Beijing Normal University (Human and Social Science Edition)*, (2), in press.
- Shi Peijun, Liu Xuemin. (2003) Construct ecology industrially, and develop industry ecologically, *Qiu Shi*, (4): 32-34.
- Margaret Palmer, Emily Bernhardt, Elizabeth Chornesky, et al. (2004) Ecology for a Crowded Planet, *Science*, (304): 1251-1252.
- Shi Peijun, Song Changqing, Jing Guifei. (2002) Strengthening the Study of Land Use/ Cover Change and Its Impact on Eco-environmental Security——the Trend of the Study of the Dynamics of Human-nature System Based on “Global Change Open Science Conference 2001” in Amsterdam, Netherlands, *Advance in Earth Sciences*, 17(2): 161-168.